Cannabis Use and Educational Achievement: Findings from Three Australasian Cohort Studies

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ABSTRACT

Background: The associations between age of onset of cannabis use and educational achievement were examined using data from three Australasian cohort studies involving over 6,000 participants. The research aims were to compare findings across studies and obtain pooled estimates of association using meta-analytic methods.

Methods: Data on age of onset of cannabis use (<15, 15-17, never before age 18) and three educational outcomes (high school completion, university enrolment, degree attainment) were common to all studies. Each study also assessed a broad range of confounding factors.

Results: There were significant (p<.001) associations between age of onset of cannabis use and all outcomes such that rates of attainment were highest for those who had not used cannabis by age 18 and lowest for those who first used cannabis before age 15. These findings were evident for each study and for the pooled data, and persisted after control for confounding. There was no consistent trend for cannabis use to have greater effect on the academic achievement of males but there was a significant gender by age of onset interaction for university enrolment. This interaction suggested that cannabis use by males had a greater detrimental effect on university participation than for females. Pooled estimates suggested that early use of cannabis may contribute up to 17% of the rate of failure to obtain the educational milestones of high school completion, university enrolment and degree attainment.

*Conclusions***:** Findings suggest the presence of a robust association between age of onset of cannabis use and subsequent educational achievement.

Keywords: Cannabis; educational achievement; meta-analysis; longitudinal study

1. Introduction

There has been increasing research into the relationships between cannabis use by young people and educational achievement. Findings suggests that young people who use cannabis early or heavily are at increased risks of educational under-achievement including: school dropout (Brook et al., 1999; Ellickson et al., 1998; Fergusson and Boden, 2008; Fergusson et al., 2003; Fergusson et al., 1996; Lynskey et al., 2003; Tanner et al., 1999; van Ours and Williams, 2009); failure to attend tertiary education (Fergusson and Boden, 2008; Fergusson et al., 2003; Newcomb and Bentler, 1988b; Tanner et al., 1999); and failure to attain university degrees (Fergusson and Boden, 2008; van Ours and Williams, 2009). These associations have been found to persist following control for confounding social, personal and related factors (Fergusson et al., 1996; Lynskey and Hall, 2000; Townsend et al., 2007; van Ours and Williams, 2009).

A limitation of this literature has been that different studies have used different samples, different methods of assessing cannabis use and differing assessments of educational outcomes, limiting the extent to which cross study comparisons can be made (Townsend et al., 2007). It has often been suggested that these limitations may be overcome by meta-analytic methods that combine findings from different studies (Curran and Hussong, 2009; Hofer and Piccinin, 2009; Mulrow, 1994). However, such analysis may be compromised by variations in study quality (Blettner et al., 1999; Egger et al., 1998). In this paper we attempt to overcome these limitations by conducting a meta-analysis of three Australasian longitudinal studies that have collected similar data on the development of cannabis use and educational achievement. Overlapping measures include: (a) the assessment of age of first use of cannabis; (b) the use of similar educational milestones that span both high school and tertiary achievement; (c) the availability of similar covariate factors spanning measures of family socio-demographic background, family functioning, individual characteristics and behaviour. These factors ensure that the meta-analysis is being applied to similar studies, conducted in similar ways and using similar measures. Unfortunately, study similarities were not sufficiently strong to extend the analyses to methods of integrative data analysis (Curran and Hussong, 2009).

More specifically, this report describes the results of a collaboration of Australasian cohort studies aimed at producing comparable analyses of the associations between early cannabis use and educational achievement. This collaboration is based upon agreements made by members of the Cannabis Cohort Research Consortium (CCRC) convened by the Australian National Drug and Alcohol Research Centre (NDARC). This consortium includes representatives from three Australasian cohort studies that have studied birth cohorts into adolescence: The Christchurch Health and Development Study (CHDS) (Fergusson and Horwood, 2001); The Victorian Adolescent Cohort Study (Swift et al., 2008) and the Mater Hospital and University of Queensland Study of Pregnancy (Najman et al., 2005).

In 2008, representatives of these studies met to explore combining findings with the aim of producing more general, more comparable and more robust findings about the linkages between cannabis use and social development in young people. It was proposed that the best place to begin this process was with an analysis of the associations between cannabis and educational achievement in all three cohorts. The aims of this collaboration were threefold: first, to examine the extent to which studies had measured cannabis use and educational achievement in comparable ways; second, to develop parallel analyses of the associations between the use of cannabis in adolescence and subsequent educational achievement; third, to combine results using meta-analytic methods to obtain pooled estimates.

This paper describes the findings from the collaboration described above. In the analysis, we look at the relationship between the age of onset of cannabis use and measures of high school completion, entry into university and degree attainment. The aims were: a) to examine the extent to which early onset cannabis use was associated with increased risks of educational under-attainment in adolescence and young adulthood when due allowance was made for confounding factors; b) to examine gender differences in the associations between cannabis use and educational outcomes; c) to obtain estimates of the size of effect of cannabis use on educational achievement; d) to examine the homogeneity of estimates; e) to obtain estimates of association and effect size pooled across studies.

2. Methods

2.1. Description of studies

2.1.1. The Christchurch Health and Development Study (CHDS). The CHDS is a longitudinal study of a birth cohort of 1265 children born in the Christchurch (New Zealand) urban region in 1977 (Fergusson and Horwood, 2001; Fergusson et al., 1989). This cohort involved 97% of children born from 15 April - 5 August 1977 and has been studied on 22 occasions to the age of 30. Data were gathered using face to face interviews with respondents including parents and birth cohort members, supplemented by data from official records. Signed consent has been obtained for all aspects of data collection and the study has been subject to ethical review throughout the history of the research. The present analysis is based on data collected during assessments of the cohort at ages 18, 21 and 25 years. The samples assessed at these ages ranged between 1003 and 1025 participants, with these samples representing between 81%-82% of the surviving cohort at each age.

2.1.2. The Victoria Adolescent Health Cohort Study (VAHCS). The VAHCS is a longitudinal study of a representative sample of mid-secondary adolescents resident in Victoria, Australia, who were born in 1977-78 (Swift et al., 2008). In 1992, participants were recruited at the end of Year 9 (wave 1) or the start of Year 10 (wave 2), and were reviewed on four occasions during adolescence (waves 3-6), with a further three follow-ups in young adulthood (waves 7-9). Of the sample of 2032 students, 1943 (95.6%) were assessed at least once during the first six waves. In wave 8 (mean age 24.1), 1523 participants (75% of the initial cohort) were interviewed and form the sample included in this report. All facets of the study have been subject to ethical review by the Royal Children's Hospital Ethics in Human Research Committee.

2.1.3. The Mater-University of Queensland Study of Pregnancy and Outcomes (MUSP). The MUSP is a 21-year longitudinal investigation that began data collection in January, 1981 (Najman et al., 2005). Pregnant women attending for their first clinic visit at the Mater Hospital were invited to participate in the study. Between January 1981 and December 1983, 8556 consecutive pregnant women were approached to complete prenatal assessments. Of those 8458 (99%) agreed to participate in the study and 7,223 gave birth to a live singleton child. These women were re-interviewed at 3 to 5 days after delivery. Additional assessments were conducted when offspring were 6 months, 5 years, 14 years, and 21 years old. At the age of 21 years, 3768 (52.2% of original cohort) completed the questionnaire and are the basis of current analyses. All phases of the study have been subject to ethical review.

2.2. Description of measures

2.2.1. Cannabis use. The most consistent measure of cannabis use across studies was the reported age of first use of cannabis coded as: 1 = <15 years; 2 = 15-17 years; 3 = never used before age 18. In the CHDS age of first use was identified on the basis of repeated questioning at ages 14, 15, 16, 18 and 21 about cannabis use since the previous assessment. In the VAHCS cannabis use was assessed at each wave using self-reported frequency of cannabis use in the previous six months, and age of first use was classified on the basis of the first wave at which cannabis use was reported. In the MUSP participants were directly questioned at age 21 about the age of first cannabis use. A second measure that was common across all studies was the reported frequency of cannabis use at age 21. This was coded as 1= daily; 2 = weekly; 3 = occasionally; 4 = never used/not currently using. For the CHDS and MUSP this measure was based on current frequency of use reported in interviews conducted at age 21. For VAHCS we used the maximum reported frequency of use in the previous year at wave 7 (average age 20.7 years).

2.2.2. Educational achievement. All studies obtained data on three important educational milestones: a) completion of high school; b) enrolment in University; c) degree attainment. In the CHDS these data were gathered in the course of interviews conducted at ages 18, 21, and 25 which included questions concerning the attainment of high school qualifications, details of tertiary enrolments and attainment of tertiary qualifications. For the VAHCS educational outcomes were assessed at ages 20, 24 (waves 7, 8) from questions asking about last year of school attended, tertiary enrolment and degree attainment. For the MUSP data were gathered at age 21 on the basis of questions relating to current educational enrolment and highest level of educational attainment. For the purposes of the present analysis each of these outcomes is treated as a separate dichotomous (0,1) variable.

The education systems in Australia and New Zealand that applied during the course of these studies were very similar. In both countries school enrolment was compulsory from age 6, with 12 years education thereafter required to complete high school; however, most children entered the school system from age 5 (known as a preparatory or kindergarten year in Australia, Year 1 in New Zealand). In both countries school was compulsory to age 15, but students could elect to leave school once they reached age 16 without completing high school. In both countries enrolment in university was subject to attaining satisfactory grades in high school examinations. The typical age at university enrolment was around age 18, with a minimum of 3 years full-time study to attain a degree qualification. Despite these similarities, there were clear differences between studies in the rates of attainment of the three educational outcomes. In particular, rates of early school leaving were typically higher in New Zealand than Australia and this is reflected in the present study in the lower rates of high school completion in the CHDS than in the VAHCS, MUSP. In addition, it should be noted that for the MUSP, information on degree attainment was obtained at age 21. It is likely that at this age, a substantial proportion of those who had enrolled in university had yet to complete their degree and as a result the reported rate of degree attainment for the MUSP is likely to be an underestimate of the proportion of the cohort who would ultimately attain a degree.

2.2.3. Covariate factors. To control associations between cannabis use and educational achievement for confounding factors, a range of covariates was selected from the database of each study. Since there was considerable variation between studies in the nature and timing of assessments of potential covariate factors the following process was adopted to identify relevant covariates. First, a listing of potential covariates was identified for each study that spanned the following broad domains of functioning known to be associated either with cannabis use or educational achievement: a) family socio-demographic background including gender, ethnicity, family socio-economic status, parental age, parental education, family living standards, family structure, parental marital status and related factors; b) child cognitive ability and educational achievement prior to the onset of cannabis use; c) measures of family functioning including parental separation/change, exposure to family violence, quality of parental relationship, parental substance use and related measures; d) measures of child/early adolescent behavioural adjustment. The selected covariates were then refined down on the basis of preliminary analysis to identify a core set of covariate factors for each study. The final covariates selected for inclusion in each study are listed at the foot of Table 3.

2.3. Statistical analysis

Table 1 summarises the associations of age of onset of cannabis use with each educational outcome for each study. This Table provides descriptive statistics for each study and also tests the significance of each association using the Mantel-Haenszel chi square test for linear trend (Mantel and Haenszel, 1959). Table 2 shows estimates of the odds ratios between the age of onset of cannabis use and each educational outcome for each study. These odds ratios were obtained from the linear logistic model:

Logit (Yij) = B0ij + B1ij Xj (EQ1)

where Yij was the ith educational outcome for the jth study, and Xj was the measure of age of onset of cannabis for the jth study. The Table also reports odds ratios for data pooled over all three studies. Estimates were obtained from pooling the parameters B1ij for each educational outcome using a random effects model (Deeks et al., 2001). Specifically, the pooled estimator (B1i) for the ith educational outcome was obtained from a weighted average of the study specific parameters ie $B1i = \Sigma_j w_{ij} B1ij / \Sigma_j w_{ij}$ where $w_{ij} = 1/(t_i^2 + s_{ij}^2)$ was an estimator of the inverse variance of the study specific parameter under a random effects model; s_{ij}^2 was the estimated variance of the sample specific parameter; and $t_i^{\,2}$ was an estimator of the between studies variance for outcome i derived using the method of DerSimonian and Laird (1986). The standard error estimate corresponding to the pooled parameter was given by s.e. $(B1i) = 1 / (\Sigma_j w_{ij})^{½}$.

Table 3 shows the estimated covariate adjusted odds ratios. Estimates were obtained by fitting the following linear logistic model for each outcome in each study:

Logit (Yij) + B0ij + B1ij Xj + Σ Bkij Zkij (EQ2)

where the variables Zkij were the relevant covariates for the ith educational outcome and jth study. The Table also reports odds ratios for data pooled over all three studies. Estimates were obtained from pooling the parameters B1ij using a random effects model. For the pooled data, Galbraith plots (Galbraith, 1988) and Cochran's Q tests (Huedo-Medina et al., 2006) were used in all cases to test for non-homogeneity of regression parameters across studies. Q test results are reported at the foot of Tables 2, 3. A p-value <.05 on Cochran's Q was taken as indicating significant heterogeneity of parameter estimates.

Gender x age of onset of cannabis use interactions were examined by extending the model in EQ2 to include a multiplicative gender x age of onset of cannabis use term. The model parameters representing this interaction were pooled over studies using a random effects model, with the significance of the pooled effect evaluated on the basis of a t-statistic derived from the ratio of the pooled interaction parameter to its pooled standard error.

Estimates of population attributable risk (PAR) were computed. The PAR estimates the percentage reduction in rates of educational under-achievement that would have occurred had all young people not used cannabis before the age of 18. Estimates of the PAR were obtained by first estimating the covariate adjusted rates of educational attainment for each level of the cannabis measure variable for each educational outcome and each study using the methods described by Lee (Lee, 1981). The covariate adjusted rate data were then pooled over studies and the resulting rate data used to estimate the pooled PAR for each outcome.

Table 4 shows a supplementary analysis linking the frequency of cannabis use at age 21 to university degree attainment. The methods for obtaining the covariate adjusted and pooled odds ratios were the same as for the analysis in Table 3.

3. Results

3.1. Associations between age of onset of cannabis use and measures of educational attainment

Table 1 shows data from the CHDS, VAHCS and MUSP samples relating to the age of onset of cannabis use and measures of educational achievement. For all comparisons, increasing age of first cannabis use was associated with increased rates of educational achievement. Mantel-Haenszel chi square tests of linearity applied to the data showed that, in all cases, there was evidence of significant ($p < .001$) linear associations. No significant non-linear trends were found.

TABLE 1 ABOUT HERE

The associations in Table 1 are summarised in Table 2, which reports odds ratios (95% confidence intervals) for each outcome. In all cases a linear model was found to be adequate. The

Table shows that in comparison to those who first used cannabis before age 15, those who had never used cannabis by age 18 had: (i) odds of high school completion that were 2.4 to 4.1 times greater; (ii) odds of university enrolment that were 1.8 to 2.9 times greater; and (iii) odds of degree attainment that were 3.0 to 4.4 times greater.

The Table also reports pooled estimates of the study odds ratios based on a random effects model. The pooled estimates indicate that those who had never used cannabis by 18 had odds of high school completion, university enrolment and degree attainment that were between 2.3 to 3.7 times higher than for those who started using cannabis before the age of 15. In all cases the Q test was non-significant, suggesting no detectable between study heterogeneity in parameter estimates.

TABLE 2 ABOUT HERE

3.2. Adjusted results

Table 3 shows the associations (odds ratios) between age of onset of cannabis use and educational achievement adjusted for confounding factors. The Table shows that in all analyses the associations between age of onset of cannabis use and educational achievement were reduced by covariate control. However, following adjustment for confounding, significant ($p<.05$) associations remained between age of onset of cannabis use and all measures of achievement.

The pooled estimates of the adjusted odds ratios show that when compared to those who began cannabis use before age 15, those who began use at age 15-17 had odds of educational achievement that were 1.4 to 1.7 times greater; whereas those who had never used cannabis by age 18 had odds of educational achievement that were 1.9 to 2.9 times greater. For one outcome, high school completion, there was evidence of significant heterogeneity of parameter estimates after adjustment (Cochran's Q(2df) = 6.22, p = .04), reflecting the fact that the adjusted association for VAHCS was more modest than for other studies.

TABLE 3 ABOUT HERE

3.3. Gender interactions

Tests of gender x age of onset of cannabis use interactions were conducted by extending the models summarised in Table 3 to include a multiplicative gender x age of cannabis use interaction term. These interaction parameters were pooled using a random effects model. The pooled interaction parameter estimates were: for high school completion (B = -0.078, SE = 0.113, p = .49); for university enrolment (B = -0.240, SE = 0.116, p = .04); and for degree attainment (B = -0.509, SE = 0.412, p = .22). In all cases the pooled interaction parameters were negative, suggesting that the impact of cannabis use was greater for males than females. However, the pooled interaction parameter was significant for only one of the three outcomes: university enrolment.

3.4. Attributable risk estimates

Estimates of the PAR due to cannabis use were calculated from the pooled data after adjustment for covariates. The pooled estimates suggested that the early use of cannabis accounted for: 17% of the overall rate of failure to complete high school; 5% of the overall rate of failure to attend university and 3% of the overall rate of failure to attain a university degree.

3.5. Supplementary analysis using frequency of cannabis use

A limitation of the results in Tables 1-3 is that these results focus on the age of onset of cannabis use rather than on the amount of cannabis used. To examine whether the same results held when measures of cannabis consumption rather than age of onset of use were employed, supplementary analysis was conducted using measures of the frequency of cannabis use at age 21 (scored as daily, weekly, occasional, never) and relating these to levels of degree attainment. The analysis is restricted to age 21 since this was the only age at which all three studies had measured the frequency of cannabis use.

Table 4 reports the associations between frequency of cannabis use at age 21 and odds of degree attainment for each study after adjustment for confounding factors. The table also reports a pooled estimate of the association obtained from a random effects model. In all cases there were clear and significant ($p<.05$) tendencies for levels of degree attainment to increase with the declining frequency of cannabis use. There was no evidence of a gender x frequency of cannabis use interaction (pooled $B = -0.231$; $SE = 0.153$; $p = .132$), and tests for between study heterogeneity were non-significant.

TABLE 4 ABOUT HERE

4. Discussion

4.1 Associations between cannabis use and educational achievement

This study has used data from three large Australasian cohort studies to examine the associations between the age of onset of cannabis use and educational attainment in cohorts of young people studied from early adolescence to young adulthood. While there is a need to be cautious about drawing causal attributions from correlational data, there are at least four lines of evidence from the present study to support a causal interpretation of the findings. First, the analysis provides replicable and comparable evidence showing that age of onset of cannabis use was related to the rate of achievement of a series of major educational milestones, including high school completion, attendance at university and degree attainment. Second, the associations had dose-response like characteristics in that the earlier the age of onset the poorer the level of educational achievement. Third, in all cases the associations appeared to be resilient to control for prospectively assessed confounding factors. Fourth, the associations were also replicated using an alternative measure of cannabis exposure based on frequency of use at age 21, with increasing frequency of use being associated with lower rates of degree attainment even following control for confounding. In these respects the findings are consistent with and extend previous research that has linked the early use of cannabis to educational underachievement (Brook et al., 1999; Ellickson et al., 1998; Fergusson and Boden, 2008; Fergusson et al., 2003; Fergusson et al., 1996; Lynskey et al., 2003; Lynskey and Hall, 2000; Newcomb and Bentler, 1988b; Tanner et al., 1999; Townsend et al., 2007; van Ours and Williams, 2009).

Against a causal interpretation of the study findings is the possibility of uncontrolled residual confounding. The associations between age of onset of cannabis use and achievement outcomes could be due to common confounding factors that were not assessed or not controlled for in the context of the three studies. For example, the analysis could not control for confounding by non-observed genetic factors that may influence both risks of cannabis use and risks of educational under-achievement. However, while the possibility that associations between cannabis use and educational achievement may be due to uncontrolled confounding factors cannot be discounted (Lynskey and Hall, 2000; McLeod et al., 2004; Townsend et al., 2007), the accumulating evidence from different studies conducted in different ways using different confounders and different methods for adjusting confounding is nevertheless consistent with the suggestion that early onset cannabis use may have a negative impact on subsequent educational achievement (Brook et al., 1999; Fergusson and Horwood, 1997; Fergusson et al., 2003; Fergusson et al., 1996; Lynskey et al., 2003; Roebuck et al., 2004; van Ours and Williams, 2009).

The issue of uncontrolled confounding aside, there are at least two other possible explanations of the observed associations between cannabis use and educational achievement. The first explanation is that the use of cannabis may, by a number of pathways, lead to increased risks of educational under-achievement. Here, several mediating mechanisms could be suggested. First, it could be proposed that the use of cannabis may have neuro-physiological consequences that lead to changes in motivation and cognitive functioning with these changes leading to impairments in educational achievement (Lynskey and Hall, 2000). While this explanation is at present speculative, it is consistent with growing research on the neurochemistry of cannabis and the vulnerability of the changing adolescent brain (Eldreth et al., 2004; Matochik et al., 2005; Quickfall and Crockford, 2006). An alternative mechanism by which the use of cannabis may lead to educational under-achievement is by introducing the young person to social contexts which encourage anti-conventional and precocious behaviours which discourage educational achievement in favour of participation in youth culture and related activities (Fergusson and Horwood, 1997; Kandel et al., 1986; Krohn et al., 1997; Rosenbaum and Kandel, 1990).

The second explanation is that the relationship between cannabis use and educational achievement arises from a reverse causal association in which educational under-achievement leads to increased use of cannabis (Green and Ensminger, 2006; Kogan et al., 2005). While this explanation has not been examined fully in this analysis, a previous study reported by Fergusson et al (Fergusson et al., 2003) using CHDS data casts doubt on the validity of this explanation. Using longitudinal data these authors were able to show that while early cannabis use was related to later educational achievement after control for confounders, school dropout was unrelated to later patterns of cannabis use after control for confounding factors. These findings are reinforced by the results of the present analysis which show that for two of the studies (CHDS, MUSP) the associations between age of onset of cannabis use and educational outcomes persisted after control for school performance prior to age 15. There is, however, a need for further analysis of the extent to which educational under-achievement encourages the use of cannabis.

In summary, the evidence is consistent with a cause and effect association in which the early use of cannabis leads, via various mediating pathways, to increased risks of educational under-achievement. The nature of these intervening pathways is not clear and there is a need for further research into the role of neuro-physiological and social processes in the linkages between early cannabis use and later educational achievement. However, notwithstanding this interpretation, there is also a need for further research that would discount possible alternative explanations of the association between cannabis use and educational achievement, including the issues of uncontrolled residual confounding and reverse causality.

4.2. Gender differences

There have been suggestions in the literature that the effects of cannabis use on educational achievement may be gender specific with the use of cannabis having greater effects on male educational achievement than on female educational achievement (Krohn et al., 1997). The present analysis produces only limited support for this view. While analysis of gender x age of onset of cannabis use interactions showed a general tendency for cannabis use to have greater effects on male achievement, for only one outcome (university enrolment) was the interaction found to be significant.

4.3. Implications

Concerns have also been raised about the potentially small effects of cannabis use on educational achievement (Hickman, 2004). This issue was examined by computing pooled estimates of the population attributable risk (PAR). These estimates showed the potential effects of early cannabis use on educational achievement to be quite substantial. The PAR estimates suggested that had all young people not used cannabis before 18: rates of high school non completion would have reduced by up to 17%; rates of university non attendance would have decreased by up to 5% and rates of non attainment of a university degree by up to 3%. These findings imply that the potential effects of early cannabis use on later educational achievement should not be dismissed as being inconsequential.

These findings add to a growing body of evidence which suggests that the early use of cannabis may be associated with increased risks of a number of adverse outcomes that span: reduced educational achievement (Brook et al., 1999; Ellickson et al., 1998; Fergusson and Boden, 2008; Fergusson and Horwood, 1997; Fergusson et al., 2003; Lynskey et al., 2003; Lynskey and Hall, 2000; Newcomb and Bentler, 1988b; Tanner et al., 1999; Townsend et al., 2007; van Ours and Williams, 2009); increased risks of mental health problems (Fergusson and Horwood, 1997; Fergusson et al., 2002; Patton et al., 2002; Rey et al., 2002); increased risks of crime (Fergusson and Horwood, 1997; Fergusson et al., 2002; Newcomb and Bentler, 1988a); increased risks of other forms of illicit drug use (Fergusson and Horwood, 1997; Fergusson et al., 2002) and increased risks of later welfare dependence and economic deprivation (Degenhardt et al., 2007; Fergusson and Horwood, 1997; Schmidt et al., 1998).

4.4. Limitations

Although it was possible to combine data from the three cohort studies there were some limitations to this process. First, because of the differences in the data collection methods used in the studies, estimates of the frequency of cannabis use were only available at age 21 and it was not possible to examine the contributions of frequency of cannabis use to high school completion. Nonetheless, the findings for the frequency of cannabis use at age 21 were consistent with the general findings on the age of onset of cannabis use to the extent that increasing frequency of use was associated with declining rates of degree attainment. Second, the analysis was limited to some fairly simple measures of educational achievement. While the outcomes used in the study defined widely recognized educational milestones, it is possible that the analysis could have been better informed by the use of a more fine grained measure reflecting individual differences in overall educational achievement.

A third limitation was that there was quite considerable between study variation in levels of attainment of the various educational outcomes. As noted previously, despite strong similarities in the education systems of Australia and New Zealand, there were nevertheless historical differences in rates of school retention between New Zealand and Australia that were reflected in much lower rates of high school completion in the CHDS cohort compared to the Australian cohorts. In addition, the assessment of degree attainment in the MUSP was incomplete. These differences could have been reflected in variations in effect size estimates across studies. However, in general effect size estimates were very similar, with Q tests providing evidence of significant between study heterogeneity for only one outcome, high school completion, and only after covariate adjustment.

A fourth limitation of the analysis was that each study used a different set of covariates assessed in different ways. However, all studies included measures of family and social functioning, childhood educational achievement and childhood behavioural adjustment as covariate factors. A further limitation related to the variations in sample retention across studies, with rates of follow-up ranging between 52% to 82% across the three cohorts. If the processes of sample attrition in each cohort were systematically correlated with the attainment of educational outcomes then this could have led to biased estimates of effect size. Finally, the results apply to Australasian populations and the extent to which similar estimates can be obtained for other populations remains to be investigated.

Within these limitations, this study suggests the presence of a robust association between age of onset of cannabis use and subsequent educational achievement, with this association being most evident for high school completion.

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Table 1
Rates (%) of high school completion, university enrolment and degree attainment by age of onset of cannabis use in each study.

Measure		Age of Onset of Cannabis Use <15 years	15-17 years	Never before 18	p
High School Completion					
CHDS	%	15.0	36.5	49.5	<.001
	(N)	(100)	(320)	(624)	
VAHCS	%	72.0	80.3	86.4	<.001
	(N)	(75)	(407)	(1036)	
MUSP	%	63.0	77.3	87.5	<.001
	(N)	(424)	(994)	(2176)	
University Enrolment					
CHDS (Age 21)	%	20.0	31.4	39.0	<.001
	(N)	(90)	(319)	(602)	
VAHCS (Age 24)	%	41.3	55.6	60.9	<.001
	(N)	(75)	(408)	(1037)	
MUSP (Age 21)	%	11.2	15.7	25.1	<.001
	(N)	(454)	(1031)	(2212)	
University Degree Attainment					
CHDS (Age 25)	%	13.0	19.7	30.5	<.001
	(N)	(92)	(310)	(601)	
VAHCS (Age 24)	%	14.7	26.7	41.4	<.001
	(N)	(75)	(408)	(1037)	
MUSP (Age 21)	%	0.5	3.5	5.5	<.001
	(N)	(424)	(994)	(2176)	

Note: Numbers in table represent the proportion of participants in each age of onset group in each study who attained the educational outcome, with the total number of participants in that age of onset group in each study given in parentheses.

Table 2
Odds ratios (95%CIs) between age of onset of cannabis use and educational outcomes for each study and pooled over all studies.

	Age of Onset of Cannabis Use			
Measure	< 15 years	15-17 years	Never before 18	p
High School Completion				
CHDS	1	2.0 (1.6-2.5)	4.1 (2.7-6.1)	<.001
VAHCS	1	1.6 (1.3-1.9)	2.4 (1.6-3.8)	<.001
MUSP	1	2.0 (1.8-2.3)	4.1 (3.3-5.2)	<.001
Pooled estimate	1	1.9 (1.6-2.2)	3.6 (2.6-4.9)	<.001
University Enrolment				
CHDS	1	1.5 (1.2-1.9)	2.3 (1.5-3.5)	<.001
VAHCS	1	1.4 (1.1-1.6)	1.8 (1.3-2.6)	<.001
MUSP	1	1.7 (1.5-1.9)	2.9 (2.2-3.7)	<.001
Pooled estimate	1	1.5 (1.3-1.8)	2.3 (1.8-3.1)	<.001
University Degree Attainment				
CHDS	1	1.7 (1.4-2.2)	3.0 (1.9-5.0)	<.001
VAHCS	1	2.0 (1.6-2.4)	3.9 (2.6-5.9)	<.001
MUSP	1	2.1 (1.5-2.9)	4.4 (2.4-8.3)	<.001
Pooled estimate	1	1.9 (1.7-2.2)	3.7 (2.8-4.9)	<.001

Note: Odds ratios derived from models that assumed a linear logistic association between age of onset of cannabis use and each outcome. Results of Cochran's Q tests for homogeneity of effects: high school completion Q(2 df) = 4.53, p = .10; university enrolment Q(2df) = 4.00, p = .14; degree attainment Q(2df) = 0.97, p = .62

Table 3
Odds ratios (95%CIs) between age of onset of cannabis use and educational outcomes for each study and pooled over all studies, after adjustment for covariates.

	Age of Onset of Cannabis Use			
Measure	< 15 years	15-17 years	Never before 18	p
High School Completion				
CHDS	1	1.9 (1.5-2.5)	3.7 (2.1-6.5)	<.001
VAHCS	1	1.3 (1.01-1.7)	1.7 (1.02-2.9)	.045
MUSP	1	1.9 (1.6-2.2)	3.6 (2.7-4.7)	<.001
Pooled estimate	1	1.7 (1.4-2.1)	2.9 (1.8-4.6)	<.001
University Enrolment				
CHDS	1	1.5 (1.1-1.9)	2.1 (1.3-3.6)	<.005
VAHCS	1	1.2 (1.01-1.5)	1.5 (1.02-2.3)	.037
MUSP	1	1.4 (1.2-1.7)	2.1 (1.5-2.8)	<.001
Pooled estimate	1	1.4 (1.2-1.6)	1.9 (1.5-2.4)	<.001
University Degree Attainment				
CHDS	1	1.4 (1.03-2.0)	2.1 (1.1-4.0)	.031
VAHCS	1	1.6 (1.3-2.1)	2.7 (1.7-4.3)	<.001
MUSP	1	1.7 (1.2-2.4)	2.8 (1.4-5.6)	<.001
Pooled estimate	1	1.6 (1.4-1.9)	2.5 (1.8-3.5)	<.001

Note: Significant covariates for a least one outcome in the CHDS included: paternal education (birth); family SES (birth); family living standards (0-10 yrs); child scholastic ability (13 yrs); teacher rated grade point average (11-13 yrs); childhood conduct problems; childhood attentional problems. Significant covariates for at least one outcome in the VAHCS included: parental education; parental smoking; gender; parental separation/divorce; childhood antisocial behaviour; born overseas. Significant covariates for at least one outcome in the MUSP included: mother's age and mother's education at child's birth, mother's marital status, marital relationship (dyadic adjustment) and mother's smoking at child's age 5 years, family poverty (between child's birth and 14 years), child gender, externalising behaviour at 5 years, and child school performance at 14 years. Results of Cochran's Q tests for homogeneity of effects: high school completion Q(2 df) = 6.22, p = .04; university enrolment Q(2df) = 1.47, p = .48; degree attainment Q(2df) = 0.49, p = .78

Table 4
Odds ratios (95% CIs) between frequency of cannabis use (at age 21) and rates of university degree attainment in each study and pooled over all studies, after adjustment for confounding.

		Frequency of Cannabis Use at Age 21				
Measure		Daily	Weekly	Occasionally	Never or not currently	p
CHDS	OR (95%CI)	1	1.4 (1.1-1.8)	1.9 (1.1-3.4)	2.7 (1.2-6.1)	.02
VAHCS	OR (95%CI)	1	1.4 (1.2-1.7)	2.0 (1.4-2.8)	2.8 (1.7-4.6)	<.001
MUSP	OR (95%CI)	1	1.5 (1.1-2.1)	2.3 (1.2-4.4)	2.5 (1.3-9.2)	.01
Pooled estimate	OR (95%CI)	1	1.4 (1.3-1.6)	2.0 (1.6-2.6)	2.9 (2.0-4.2)	<.001

Note: Significant covariates for the CHDS included: paternal education (birth); family SES (birth); family living standards (0-10 yrs); child scholastic ability (13 yrs); teacher rated grade point average (11-13 yrs); childhood conduct problems. Significant covariates for the VAHCS included: parental education; parental smoking; gender; parental separation/divorce; childhood antisocial behaviour. Significant covariates for the MUSP included: mother's education at child's birth, marital relationship (dyadic adjustment), mother's smoking at child's age 5 years, child gender, child school performance at 14 years. Results of Cochran's Q test for homogeneity of effects: Q(2 df) = 0.20, p = .90